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UNITED STATES
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BUREAU OF MINES
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SAFETY PRACTICES AT UNITED VERDE MINE

PHELPS DODGE CORP., JEROME, ARIZ.

BY

ALLEN D. LOOK AND ALAN A. SHARP

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SAFETY PRACTICES AT UNITED VERDE MINE, PHELPS DODGE CORP., JEROME, ARIZ.[1]

By Allen D. Look[2] and Alan A. Sharp[2]

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INTRODUCTION

The bottoming of the United Verde sulfide pipe has shortened the expected life of the United Verde mine to a matter of a few years. First located in 1876, this Arizona mine has had a long period of activity, having reached a peak production in 1929 of over 71,000 tons of copper. Through these many years of successful operation, a safety program has evolved in keeping with the proficiency developed in mining the ore body. It is the purpose of this paper to record the safety practices in effect at this mine so that others may have the benefit of lessons learned through experience and years of work toward an improved accident record.

ACKNOWLEDGMENTS

Acknowledgment is made to the Phelps Dodge Corp. for its cooperation in making available data contained in this paper, and to C. E. Mills, general superintendent; W. W. Little, mine superintendent; John Riordan, employment agent; and G. S. Leisk, safety engineer, for their helpful suggestions and information furnished.

GENERAL INFORMATION

The United Verde copper mine is situated just west of Jerome, Ariz., at an altitude of approximately 5,500 feet. Purchased by the Phelps Dodge Corp. in 1935, the mine employs approximately 500 men - 385 underground and 115 on the surface.

According to Quayle3/, the ore deposit is an irregular chimney of massive sulfide of a typical schist-replacement type. The sulfide ore deposits were formed after the intrusion of an augite diroite into schistose quartz porphyry. The irregular interfingering of the sulfide with the schists and unmetamorphosed porphyry forms an irregular and indefinite footwall boundary. The main ore bodies occur along the contact of the massive sulfide and the schist, with smaller and less important ones on the schist-porphyry contact or entirely in any one of the three rocks. The massive sulfide is generally very hard and dense and stands well over large areas without timber support except for an

3/ Quayle, T. W., Mining Methods and Practices at the United Verde Copper Mine, Jerome, Ariz.: Bureau of Mines Inf. Circ. 6440, 1931, pp. 3-4.

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occasional bulkhead under a loose slab or where weakened by an andesite dike. The schist varies in hardness and strength in different parts of the mine. In hardness and strength the porphyry forms an intermediate class between the massive sulfides and the schist, and the ore bodies in it can ordinarily be mined by the cut-and-fill method.

The mine is opened by two adit levels and three operating shafts. Ore is hoisted through No. 5 shaft, which has its bottom loading pocket at the 3,000-foot level. The hoist room is on the 1,000-foot level, and the unloading pocket is at the 800-foot level. No. 6 shaft is a service shaft sunk to the 3,000-foot level, with the hoist room on the 500-foot level. The No. 8 shaft, with hoist room on the 3,000-foot level, extends to the 4,500-foot or bottom level and is used for both hoisting and service. Men and supplies are transported through the 500-level service tunnel connecting the mine surface plant with No. 6 shaft. Ore is transported from No. 5 shaft bins on the 1,000-foot level to surface through the Hopewell tunnel (6,600 feet in length) to the outside ore bins.

SAFETY DEPARTMENT

The mine safety and employment department has three employees and is supervised by the employment agent. A safety engineer is in charge of all underground inspections, safety-school instruction, mine rescue training, and related duties. A stenographer does the typing, filing of records, issues safety equipment to the men, edits and distributes copies of reports of meetings, accident reports, inspection reports, and codes of safe practice.

Although the safety department coordinates all safety and educational activities, investigates accidents, and follows up on safety suggestions, it serves mainly in an advisory capacity. All suggestions made by the safety department are acted upon promptly, but the enforcement of safety rules is part of the duties of the supervisory staff. The safety department keeps a record card for each employee, which shows any disciplinary action, first-aid or mine rescue training of the individual, dates of medical examinations, compensation drawn, record of attendance at safety training classes, and dates of employment. When a man is re-hired, his original card is used to continue the record of his employment.

The safety department is represented on all safety committees. It obtains information on safety activities and practices from other companies, the National Safety Council, safety magazines, and Bureau of Mines publications. Appropriate material is selected for use at safety meetings, and the department also prepares the monthly safety summary read at the unit meetings. The material used is not always confined to mine safety but may contain messages on safety at home or on the highway.

All new workers are given a thorough physical and X-ray examination at the company hospital. Any previous employees applying for re-employment must be re-examined. All men employed for underground work must complete 5 hours of training and instruction in safety school classes and men with little underground training are assigned to work with experienced employees who instruct them in the proper methods of doing the job.

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SAFETY COMMITTEES AND MEETINGS

The impetus for the safety program of the Phelps Dodge Corp. comes from the top management and is carried down through the entire organization by a coordinated series of committees. Every employee participates through membership on a safety committee and attendance at the committee meetings. The general safety policy and standardization of the Corporation's program is determined by the Corporation safety committee, consisting of the manager and general superintendents of the various branches. Meetings of this committee are held annually.

The United Verde branch safety committee consists of the department heads of the smelter division at Clarkdale, Ariz., and the mine division at Jerome, Ariz. This group meets monthly with the general superintendent, acting as chairman, to consider problems of the branch.

Mine division safety activities are covered by the mine and mechanical bosses' committee, composed of the underground and surface supervisory force. The mine superintendent acts as chairman of the monthly meetings of this group.

All employees are members of unit committees divided into groups under the various supervisors. Men working in the same part of the mine are grouped for the unit safety meetings, which are held every month underground during the work shift. Surface employees convene in the morning or after lunch in the respective shops. All units, both surface and underground, hold their safety meetings on the same day. The groups are composed of 10 to 40 men, the average being about 25.

The supervisor acts as chairman and must prepare suitable material for the meeting, aided by a suggested outline from the safety department. The usual agenda is reading the minutes of the previous meeting, followed by a report of lost-time and no-lost-time accidents since the last meeting. Instructions on safe practices are given by the chairman, and attention is called to any poor practices observed in the chairman's field of supervision. The action taken on all safety suggestions submitted at the previous meeting is explained. A secretary is appointed for each unit meeting to keep the minutes of the meeting. These minutes are typed for the safety office files, and copies are given to the general superintendent, mine superintendent, department head, and direct supervisor.

The men are urged to submit safety suggestions verbally, and the unit meetings are the major source of safety suggestions. The suggestions are recorded on a standard form and submitted by the secretary with the minutes of the meeting.

SAFETY SUGGESTIONS

Although most safety suggestions originate at the unit safety meetings, employees are encouraged to submit suggestions at any time to any member of the supervisory force or safety department. Numerous plant and working-practice improvements are the direct result of safety suggestions.

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To encourage continued receipt of suggestions, prompt, definite action must be taken on all proposals offered by the workmen. Processing of safety suggestions is therefore a primary consideration at the United Verde mine. A printed follow-up form is made out for each suggestion and is referred to the proper authority for decision. If practical, the idea is carried out at once. If impractical, the worker is told why his plan was rejected. If the suggestion is involved or calls for research, the suggestion is held as pending, action being taken as quickly as possible.

In 1947, 258 safety suggestions were received. Of these, 87.2 percent were carried to completion and 12.8 percent were rejected, no suggestions being carried over as pending.

SAFETY INSPECTIONS

Alternating with code reviews, safety inspections are held underground every other month to determine whether:

1. The mine is in good physical condition.
2. Equipment is in good working order and properly guarded.
3. Open manways or other openings are in usable condition and properly guarded.
4. Good housekeeping is practiced.
5. Men are properly clothed and supplied with safety equipment.
6. Men are supplied with the necessary codes of safe practice.
7. Men are working in accordance with codes of safe practice.
8. Supervisor keeps his department up to Company safety standards.

Underground safety inspections of the "runs" covered by each shift boss are made by a safety committee, which consists of the safety engineer and two wage employees from that particular "run." The latter two men are selected by the shift boss and changed every 3 months. Every 6 months, each shift boss on day shift and the safety engineer makes a thorough safety inspection of the entire area supervised by that boss. There are four such operating units or bosses' "runs."

Check lists are available with space for marking defects. Seven copies of the report are typed and distributed to the shift bosses on both shifts, the master mechanic, the chief electrician, the mine superintendent, the manager, and one copy for the safety department file. The copies to the direct supervisors must be returned to the safety department within a week with a statement as to the action taken on items for which the recipient is responsible. Defects still pending after reports are returned are taken up verbally with the department concerned, if there is an unexplained delay. Additional inspection check lists are provided for the Hopewell tunnel and a combined check list for hoisting, ventilation, fire patrol, and outlying repair work.

In addition to the scheduled inspections, spot inspections are carried out by the safety engineer with his other duties. When passing through the mine, he lists any unsafe practices or conditions noted. The list of defects noted is sent to the mine foreman, a copy going to the mine superintendent. The mine foreman takes up the items for correction with the shift boss concerned.

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In the shops, departmental safety inspections are conducted by a surface safety inspection committee every other month, plant inspection forms being used to record the findings. These forms are studied at the first meeting of the committee. The second meeting is used for the inspection, and a last meeting reviews the follow-up form, lists all defects, and discusses general shop safety conditions. The inspection forms cover yards and approaches, buildings, ventilation, light, sanitation, fire and explosion hazards, fire-fighting apparatus, building equipment, first-aid supplies, exits, and outside explosives magazines. The items to be inspected are arranged on the check lists so that the condition of the pertinent points to be noted can be designated by yes or no answers. When substandard conditions are noted, the safety committee writes a description on the opposite blank page, with suggestions or recommendations for correction of the faults.

Inspection codes and outlines also are provided for all equipment requiring daily, weekly, or monthly inspection by the operator or maintenance departments. Inspection forms used for railroad equipment, such as steam or gas locomotives, cranes, etc., are inspected under Interstate Commerce Commission regulations, which include space for a sworn affidavit by the inspector or operator.

All operating shafts are inspected weekly by the mechanical department, and reports are made to the general mine foreman on standard inspection forms. Safety dogs are tested once a week, together with a standard inspection of the hoisting ropes. Before lowering the shift, designated men check daily all fastenings on hoist and cages, check the wrap on the drums, and one clearance trip is made through the shaft. Both ropes are watched closely on the first man-trip. From 6 feet to 15 feet of sound rope is cut off every 6 months and the rope is resocketed. The drum end is also cut back, and the fastenings are renewed periodically.

A machinist examines the main operating hoists daily and makes a formal detailed inspection weekly. An electrician examines all switchboard contacts during the lunch period and makes a thorough inspection every week. Qualified boilermakers examine the cage daily and inspect the cage, guides, counterweight, and shaft timbering on a weekly basis. The results of the weekly inspection are written up on standard inspection forms. The hoistman tests the brakes and limit switches, along with a general inspection of the hoist and equipment at the beginning of the shift.

SAFETY EDUCATION

Codes of Safe Practice

When the Phelps Dodge Corp. took over the United Verde property in 1935, the management evolved the idea of drawing up rules to cover each phase of operation in the mine, mill, and smelter. Charles R. Kuzell, then smelter superintendent, inaugurated this unusual system, which became known as the Codes of Safe Practice.[4/] Key officials or bosses were chosen from various departments

4/ Anundsen, E. A., Accident Prevention at a Copper Smelter: Bureau of Mines Inf. Circ. 7061, 1939, pp. 12-16.

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to write detailed safety instructions. The preliminary draft was then submitted to the foreman, superintendent, shift bosses, and the safety department for discussion, and was revised before being printed in the final form. The company went to considerable labor and expense in preparing, publishing, and enforcing these codes, but the results achieved have been very satisfactory. The other branches of the Corporation are now preparing and adopting codes similar to those used at the United Verde Branch. A thorough study of all available published information on each subject was made from such sources as:

National Safety Council Safe Practice Pamphlets
National Board of Fire Underwriters
Institute of Makers of Explosives
U. S. Bureau of Mines
Insurance companies
National Electrical Safety Code
Equipment manufacturers
Safety rules of other companies
State laws

Many of the rules resulted from practical experience obtained locally, accidents, and near-accidents during previous years.

Written matter is supplemented in the codes by diagrams and sketches to clarify many of the detailed instructions. Current changes or revisions are made as inserts to the various codes and incorporated as a part of the code, when new copies are printed.

The following codes of safe practice have been adopted by the Mines Division:

SURFACE SHOPS

Overhead cranes
Crane operations, Browning and Osgood
Drill-sharpening shop
Steam hammers, blacksmith shop
Trip hammers
Carpenter shop
Framing shop
Paint shop
Operating lathe
Boiler-shop machinery
Drill repair shop
Blacksmith shop
Salvage shop
Metal working drill presses
Metal shapers, machine shop
Threading and bending pipe
Arc welding
Cutting tanks or sealed containers with the oxy-acetylene torch
Compressor operation
Equipment supplementary to the air compressors
Changing and operating boilers at the 500-level heating plant

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MISCELLANEOUS SURFACE

Surface watchmen
Storing and handling of fuel oil
Flammable liquids
Leach plant

HAULAGE

Outside Hopewell haulage and loading crews
Use of V. T. & S. R. R. by locomotives other than V. T. & S. equipment
Unloading steel from railroad car
Loading mine timbers
Hopewell tunnel operations
Underground haulage and handling supplies
Handling car samples
Trolley and trolley locomotives
Battery locomotives, batteries, charging panels, and fans
500 adit tunnel haulage

MINE RESCUE, FIRES, DUST

Mine rescue equipment
Fire protection 500 surface plant
Mine fires
Mine dust control

UNDERGROUND MAINTENANCE

Track maintenance crew
Underground pipe work
Underground watchmen

SHAFTS

Duties of hoist engineer from electrical standpoint
Preliminary preparations before operating hoist
Instructions for hoist engineers
Attaching wire rope sockets
Shaft hoistman, skip tenders, and cagers

EXPLOSIVES

Handling explosives
Unloading powder from railroad car to magazine
Handling and transporting dynamite from mine to surface destinations
Transporting and distributing underground explosives
Fuse magazines
Electric blasting on 900 grizzlies
Electric blasting in stopes
Electric blasting at tunnel ore bins
Blasting sequence for operating levels

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UNDERGROUND OPERATIONS

Handling Timken bits
Drift mining
Raise mining
Stope mining
900 grizzlies
Calyx drill operations
Operation of mine pumps

OPEN PIT AND SHOVEL DEPARTMENTS

Coordination between open pit and underground department
Bank mining
Machine drilling operations
Churn drilling
Installation and maintenance of water and air lines
Storing, handling, and transporting explosives
Wiring shots and care and operation of blasting switches
Springing and loading machine drilled holes
Adobe blasting
Miscellaneous jobs of the powder gang
All shovel operations
Shovel maintenance
Truck operations
Truck maintenance
Inspection, care, and operation of caterpillar tractors
Care and use of Comfo respirator
Lime quarry bank mining
Lime quarry crushing plant

ELECTRICAL

Electric cranes
1,000-level fan
Electrical bonding
Lime work
Electrical department, general underground precautions
Underground electrical maintenance
Edison battery cap lamps
50-B shovels
Pit substation
Electrical blasting circuits
Electric cables
Electricians' helpers shop, underground, and surface

FIRST-AID TRAINING

Elementary first-aid-training and handling of injured employees

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Education of New Men

In order to instruct the men in safety practices as outlined by the codes, the general safety rules and regulations and basic codes are first taught in the safety school. A plan of examinations, both oral and written, has been used in the past after code training, and all employees are required to attain a grade of at least 60 percent. Previous to any permanent change in occupation, the employee is furnished with the code or codes pertinent to his new job. Following his change in occupation, an examination is given to insure his familiarity with his new duties. Surface employees review their codes every 6 months. During alternate months, the underground workers review the codes applicable to their particular work.

All men employed for underground work, regardless of previous experience elsewhere, are required to take 5 hours' instruction in the safety school, usually within the first 2 months of employment. Classes are scheduled at maximum intervals of 2 months, or more often if enough new men have been hired to make up a group of 20. During the first hour the men receive preliminary instruction and advice from the employment agent, the foreman, and shift boss. This is followed by 4 hours of classroom work given by the safety engineer. Classes are held outside working hours, and attendance is paid for as overtime.

The first classroom meeting is an introduction to mine safety. The benefits to each individual of working safely are emphasized. The correct use of proper hand tools is demonstrated. The second lecture deals with handling and placing timber in stopes, drifts, and raises, and the hazards of various equipment used underground. The next class covers the handling and use of explosives and study of basic codes of safe practice, along with the general safety rules and regulations. During the last class, a review of the preceding lectures is followed by questions from the men. A final written examination based on the material covered concludes the 5-hour course.

The safety school is well-equipped. A standard square-set or stope lead set is installed, as well as a pneumatic drill, tugger hoist, slusher, stope grizzly, pedal-operated spray for allaying dust, and cage and bell signals (fig. 1). All the common hand tools used underground are on display, and the correct use of each tool is explained by the instructor (fig. 2). The danger of striking hard metal to hard metal is emphasized, and instructions are given in removing detachable bits, wedging eye bolts, use of proper safety goggles, etc.

National Safety Council posters are used widely around the mine and surface plant. Goggles and other safety equipment damaged in actual use are exhibited in the safety office, safety school, and elsewhere. Warnings are posted extensively, as well as rules for operation of various pieces of equipment.

Although the development of safety rules is not difficult, safety rules alone are of little value in preventing accidents. However, when all employees are required to become familiar with the rules and compliance is strictly enforced, such rules, if carefully and comprehensively prepared, are most

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Figure 1. - Safety school classroom, with timber sets and mine equipment in background.

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Figure 2. - Display of hand tools used in safety school instruction.

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effective in accident-prevention work and improved operating efficiency. Enforcement of the codes is the responsibility of the shift boss and foreman. Depending on the nature of the infraction of any safe practice, the offender is given a written warning for the first offense, followed by a short lay-off if it is repeated. New employees are given a verbal warning only for the first offense.

Improper guarding when blasting, misuse of explosives, and failure to follow several other well-established rules are cause for immediate discharge.

ACCIDENT INVESTIGATIONS

The purpose of accident investigations at the United Verde mine is to determine the facts, attempt to arrive at a means of preventing a recurrence, and to classify the accident as to fault and cause. Investigations are made of all accidents involving personal injury and property damage and near accidents. Following such an occurrence, a report is made by the direct supervisor after an immediate investigation. This report is submitted to the safety department on a prepared form with copies to the department head and mine superintendent.

All lost-time injuries and certain no-lost-time injuries or accidents involving property damage with potential serious consequences are investigated formally by a committee. The investigating committee is composed of the department head, three or four wage employees, and a member of the safety department. Three wage employees are on the committee to investigate surface accidents, each picked from a different shop. Four wage employees are on the underground committees to enable the appointment of one man from the crew of each shift boss. This makeup gives wider publicity to the findings of the committee. The investigation is made on the same respective shift as the one on which the accident occurred, never later than the following day.

Investigations are conducted at the scene of the accident. Witnesses and the direct supervisor are questioned as to instructions issued and circumstances leading to the accident. A statement is obtained from the victim when possible. On receipt of all evidence, the investigating committee makes a finding as to cause and fault and offers recommendations on prevention of similar accidents. Action taken on the recommendations of the committee depends upon the extent of the recommendations. Immediate direct action by the department head involved may suffice to clear the situation, or further study may be indicated to reach a satisfactory solution. A concise discussion of the accident is written for the monthly accident report, but the findings as to fault and cause appear in the same report only in the statistical tables, without reference to specific accidents.

On normal no-lost-time injuries and other accidents not involving personal injury, a report is turned in by the supervisor, as in the case of a lost-time accident. These accidents are investigated by a member of the safety department in direct interview with the person or persons involved, when possible at the scene of the accident. The investigator discusses means of prevention with the employee and classifies the accident as to cause and fault.

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Recommendations can be made if needed and handled the same as those offered by an investigating committee. A brief summary of the accident is written for the monthly accident report.

SAFETY IN OPERATIONS

Development and Stoping

Fall of Ground

The remaining ore reserves at the United Verde mine exist as vertical pillars, floor (flat) pillars, open stopes, and some small ore areas on the lower levels. The open stopes are mined by inclined cut-and-fill and shrinkage methods, one stope using the Aldermac system. The vertical pillars are mined by Mitchell slicing; floor pillars present various problems and are mined by either square-set methods or Mitchell slicing. Development drifts require but little timber, but gangways in the upper levels and pillar sections are heavily timbered. Raises are either stulled or square set, depending on the purpose of the raise. These operations require constant vigilance to prevent accidents from falls of ground, and this fact is recognized in the instructions and supervision given the men. The nature of such instructions is indicated by the following quotation[5] from the published rules each miner is issued:

Barring down.

1. Examine the back before starting work and at frequent intervals during the shift.

   Have a bar of sufficient length so that the person barring down may stand in the clear of falling rocks and will not lose his balance in reaching high points. The bar should be sharp and straight. Use the specially constructed bar for trimming high backs. Do not use a pick or other tool for barring down.

2. Have a secure footing and take such a position that falling rocks cannot roll toward you.

3. Start barring from a safe place and make the ground safe before advancing under it.

   It is safer to work from the top downward if conditions will permit it.

4. Guard against rocks sliding down the bar. If a rock slides down the bar, drop the bar.

5. It is better to raise up rather than push down on the bar when prying. In event of slipping, one will not fall toward the dangerous ground.

6. Bar down back and walls of stope, being particularly careful to go back and try all rocks that appeared loose on the previous day.

5/ Phelps Dodge Corp., A Code of Safe Practice for Stope Mining: Jerome, Ariz., 1946, pp. 1-2.

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7. If rock sounds loose but cannot be dislodged by two or three bars, notify the boss, who may have it stulled or drilled and shot. If the boss is not immediately available, make it safe.

8. Allow no one to pass under dangerous or drummy ground until it has been made safe. If the area is large and cannot be caught up immediately, see that it is fenced off.

9. Pay particular attention to barring down along slips, where a change of ground occurs; at the raises leading to level above; or where there is water seepage, which may loosen the ground.

10. The jarring of the drill may loosen material that previously appeared tight. Try the back frequently when drilling.

11. Test all suspicious rock or ground. Striking the back produces vibration and sound. A "drummy" or hollow sound usually indicates that the material is loose, but absence of sound does not always indicate that it is safe. Vibration usually can be felt by the bare fingers or hand in contact with the material being tested. The amount of vibration produced when the material is struck is a better indication of its firmness or looseness. Where feasible, this method should be used in conjunction with the sound test on all questionable ground. Condition, location, and size of slips also are to be taken into consideration.

12. Keep the muck pile well-sloped at all times, making sure to bar down any loose boulders that may be lodged at the top of the slope.

13. Advise engineers, nippers, or other persons entering the stope of any unsafe condition.

14. If mining is being done in very heavy or fractured ground without the protection of timbered sets, make use of umbrella stulls or props for temporary protection.

15. Bootlegs:

    a. Clean out, wash, and examine all bootlegs. Use the copper scraper for cleaning out bootlegs. Bootlegs containing powder shall be treated as missed holes.

    b. Missed holes shall be shot according to the bosses' orders and machines shall be set up according to his instructions, where missed holes exist.

The above rules are not only handed to the miner in published form, but he is also given instructions concerning them and finally an examination, as described previously under Codes of Safe Practice.

A standard system of timbering is followed, 10- by 10-inch Oregon pine or fir timbers being used, except for heavy ground, where 10- by 12-inch or 12- by 12-inch is used.

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Stoping

Electric lighting is carried into all active stopes. Manways are well-constructed, with the timber slide in the corner fenced off to protect the men. Vertical raises over 50 feet high have staggered ladders and platforms at intervals no greater than 20 feet, whereas in inclined raises planks are placed across from hanging wall to foot wall at the same interval. All water and air lines serving raises are provided with valves near the bottom of the raise. Grizzlies with 75-pound rails spaced 11 inches apart must be placed above all stope chutes. Chutes are covered by 3-inch planks when not in use.

Cut-and-fill stopes are gob-filled after each successive cut. In addition to rock from development headings, waste for stope filling is mined by electric shovels on the surface and trucked to a main waste raise serving the mine. A waste transfer raise, from which material may be drawn on each of the operating levels, assures ready distribution and availability of this material when needed.

Mechanical Loading

Muck is handled by mucking machines in drifts and by slushers in stopes. The hazards of mechanical loading and operation of equipment are covered in detail in the applicable codes of safe practice.6/ 7/

Explosives and Blasting

The main explosives magazine, situated at a safe distance from the portal of Hopewell tunnel, is well-isolated from the rest of the plant and 1,700 feet from the nearest inhabited building. It is of wooden construction, with sand-filled walls and roof covered with corrugated iron. Ventilation holes of offset-type construction are protected by metal screening. Illumination is by natural means. A woven-wire fence with locked gate encloses the magazine. There are also small auxiliary dynamite and detonator magazines for surface use.

Underground magazines are in short, dry crosscuts with a screened steel-bar door hung in a concrete frame. Danger and instruction signs are posted on the doors and inside the magazines. Floors are concrete, the boxes of explosives being stacked on wooden platforms. Illumination is by electric lights with explosion-proof covers, and wiring is in conduit. A red-painted box is provided in each magazine for waste dynamite, which is picked up weekly and destroyed. A metal container outside the magazine holds hot wire spitters, which are kept dry by means of an electric light. Each underground magazine is under the care of the tool nipper in that section of the mine. A red light above the track opposite the magazine warns the haulage crews to approach with trains under control.

6/ Work cited in footnote 5.

7/ Phelps Dodge Corp., A Code of Safe Practices for Drift Mining: Jerome, Ariz., 1943, 14 pp.

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Detonators are stored outside the 500-level tunnel, beyond the shops, in an isolated concrete building with double-locked steel doors backed by planks. All fuse is capped on the surface in a building not far from the detonator magazine. A compressed-air-operated cutter cuts 10 fuses fed from 10 rolls at a time. The fuse is capped by means of a foot lever-operated crimper, and a monthly sample is taken from each of 10 rolls for a burning test. Fuse is cut into three standard lengths - 5 feet for chute blasting and breaking boulders, 9 feet for stopes or drifts drilled with holes 6 feet or less, and 12 feet for raise rounds and stope holes exceeding 6 feet. All fuse is capped with Western "Big Inch" No. 6 detonators. No fuse less than 5 feet in length is used for any purpose. In cutting off fuse for blasting sequence, 18 inches is the maximum permitted on 9-foot fuse and 36 inches for 12-foot fuse. Where boulders are blasted in stopes in conjunction with a stope round, 9-foot fuses are used. Fuse is delivered to the mine with strings around the detonator end of the fuse for tying to the stick of powder when making up the primer. Fuse to be used in wet holes is dipped in sealing compound after capping to waterproof the area near the crimp and hung up to dry. Capped fuse is stored underground on half-round wooden racks. A red box is placed in underground detonator magazines for temporary storage of old detonators to be destroyed.

Explosives are delivered to the main surface magazine in railroad cars. Delivery is made into the mine in a special steel car with wooden lining fastened by copper nails, transported through the Hopewell tunnel by a trolley locomotive after the track is cleared. An empty truck is required between the locomotive and the powder car. At the No. 6 shaft station the boxes are transferred to timber trucks with special wooden frames, lowered, and hand-trammed to the magazines by a distribution crew, during the lunch period. Each miner picks up his own explosives in sacks, making a record of the number of sticks used. The miner must return unused dynamite to the magazine after blasting. Capped fuses are transported into the mine coiled in special wooden boxes painted red. Dynamite and fuse may be transported together by the miner but must be in separate sacks, one hung over each shoulder.

The miner prepares primers by punching a diagonal hole in the side of the 1-1/8- by 8-inch cartridge about 1-1/2 inches from the end with a wooden skewer. The hole penetrates lengthwise deeply enough for the entire detonator to be completely inserted. The fuse is then tied to the cartridge just above the insertion.

The primer is placed in the bottom of the hole. The primer is never slit or tamped, but another stick may be placed in the hole at the same time to hold it. The remaining sticks are placed one at a time and tamped by pressing firmly. Double primers are never used; wet-hole primers are made with waterproofed fuse.

Stemming consists of river silt loaded in paper cartridges by means of a special machine developed in the shops. All holes require at least one stick of stemming.

Two men are present while spitting, and no more than 15 holes are spit by one man. Fuse is lighted by 12-inch hot-wire spitters, which burn an average of 2 minutes and 20 seconds. With 9- or 12-foot fuse, everyone must

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leave when the spitter has burned out, regardless of whether or not spitting or the round has been completed. With 5-foot fuse, everyone must leave when the spitter is half burned down. Timbers and surrounding areas are wet down before blasting.

Missed holes are blasted on instructions from the supervisor by removing the tamping with a copper scraper and inserting a new primer. Bootlegs are cleaned out with a copper scraper and washed thoroughly with water prior to setting up the machine. If a bootleg is found to contain explosives, it is treated as a missed hole. No one is allowed to return to the blasting zone sooner than 30 minutes after firing a round, where a misfire is suspected.

All blasting in transfer raises and on shaft grizzlies is done electrically with instantaneous detonators connected in series and fired by a blasting machine.

Schedules are posted at all shaft stations for blasting at the end of the shift. Starting from the top operating level, each level blasts at 5-minute intervals. Electric signal boxes are installed on each level for signaling. Before blasting, the miners must receive and acknowledge a signal from the level above. After blasting, the level below is then signaled and must also acknowledge the call. Telephones are available near the signal boxes in case of breakdown of the blasting-signal system. The only exception to blasting at the end of the shift is in heavily timbered sections. Because of the fire hazard plus the danger of shooting out timbers, this ground is blasted during the shift, and inspection made as soon as practicable.

Haulage

Ore is transported to surface through Hopewell tunnel with a 25-ton trolley locomotive and trains of eight 40-ton standard-gage cars. Trolley locomotives are used on the 500, 1,000, and 3,000 levels, with storage battery-operated 4- and 6-ton locomotives on the other active levels. Enclosed standard-gage cars with a capacity of 26 men are used in transporting men from the change room to No. 6 service shaft. Horseplay is prohibited; the doors are kept closed while the train is in motion; the train must come to a full stop before men may enter or leave the cars.

At the beginning of the shift, the locomotives are inspected to see that the horn, headlights, and brakes are in proper working order. The sanders must be kept full of screened dry sand, and convenient supplies of sand are kept on each level. Cars in bad order are sent to surface for repairs.

Trains are operated at a safe speed at all times and are not operated in main haulage drifts when the shift is coming on or off. The motorman is in charge of the train at all times. Only men familiar with the level and who know the locations of all ventilation doors, switches, curves, grades, and chutes are employed as motormen or switchmen. Only the motorman rides on the locomotive, and he is instructed to keep all parts of his body inside the cab. Whenever possible trains are pulled, and the switchman rides the rear of the last car. A platform is provided for chute pullers at the height of the chute lip and on the opposite side of the drift from the chute. An additional hinged

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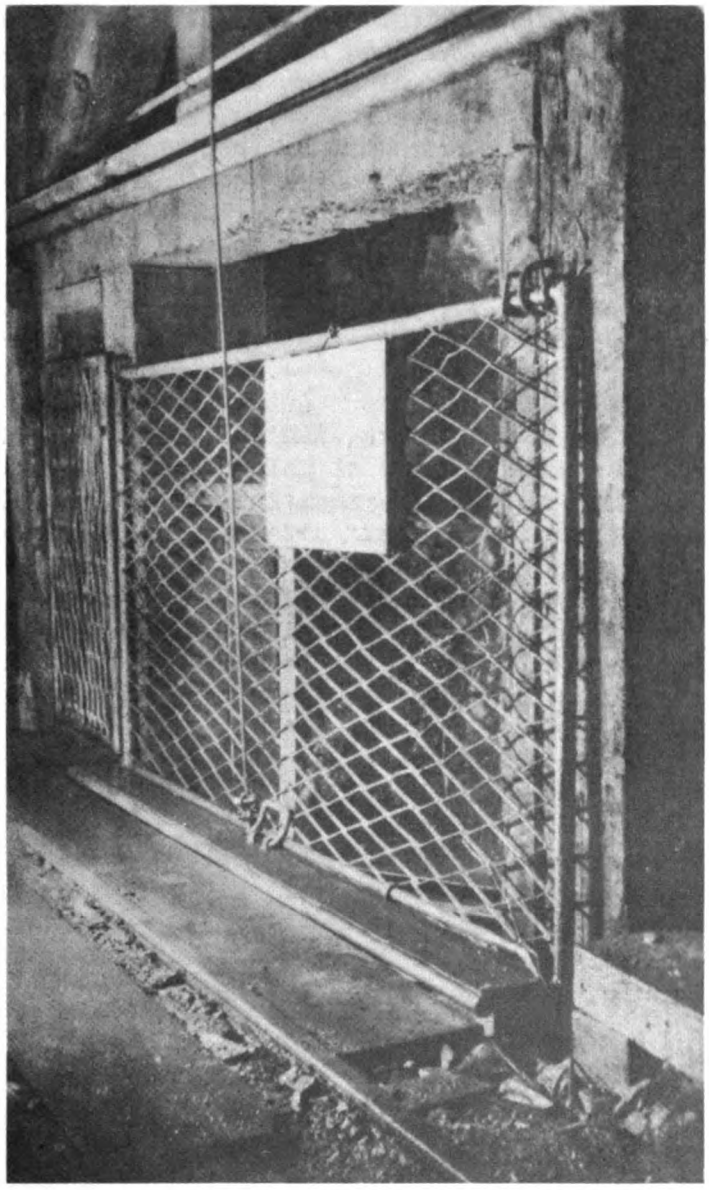

Figure 3. - Screen guard at waste raise.

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platform constructed at one side of the chute can be dropped across the drift to rest on the first-mentioned platform well above the top of the car. This arrangement provides the chute puller with a secure place from which to work and allows him to keep in the clear. Well-designed steel chute gates give good control of the flow of material from the chutes and minimize spillage.

When handling ore, the trains dump at the shaft pocket grizzlies. No. 5 shaft grizzlies are constructed of inclined, 90-pound, inverted rails with 3/4-inch wearing plates and spaced with 9-inch openings. The flat portion of the grizzly has 12- by 15-inch openings. When passing muck through the grizzly, safety belts and chains are used. The chain is fastened to a cable stretched across the rear of the grizzly chamber. Boulders are handled with hooks or bars to prevent hand or foot injuries. A bumper rail prevents cars from overturning on the grizzly, and car stops prevent the rocker-bottom cars from returning past center when uprighted.

Sufficient clearance is provided at all stope fill raises to prevent arm injuries when dumping cars. The tops of all waste dumps are provided with rail grizzlies and are guarded with hinged pipe and mesh-counterweighted lift gates (fig. 3).

Roadbed and track are well maintained, and drainage ditches are covered where they cross the track. Smelter slag is spread between the rails to afford good footing in wet places. Spring switches are used in special places for protection against inadvertently running a train into a shaft area.

Hoisting

The possible serious results of any hoisting accident are fully realized at this mine, and recognized standards of safe hoisting practices are followed. Three vertical interior shafts are in operation: No. 5 ore-hoisting shaft and No. 6 service shaft serving the mine to the 3000 level, and No. 8 service and hoisting shaft from the 3000- to the 4500-foot level.

All hoists are of a standard design and provided with approved safety devices. Each hoist is equipped with two independent brakes capable of holding a full load at any point in the shaft. Accurate indicators allow the hoistmen to determine the positions of the skips and cages at all times. Automatic overwind and overspeed devices and a slack-cable warning system are provided and maintained.

The underground hoist rooms are lined with reinforced concrete and are quiet enough to allow the hoistman to hear the signals readily. All hoistmen are given an annual physical examination. A mechanic is present at the hoist when the shift is lowered or raised.

Various means of signaling are used. A two-way call system with a push button on each level is used to call the cage. The signal is registered in an annunciator box, which enables the hoistman to determine the level from which the call was given. The hoistman acknowledges the call with a light flash. The cager has a special signal system, which no one else is permitted to use. It also registers in an annunciator box, so if some person wilfully or innocently

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rings from another level the fact is apparent to the hoistman. A radio signal from the cage to a squawker in the hoist room can be transmitted from any place in the shaft, regardless of cage speed, by means of an electronic device that induces a carrier current in the hoisting cable. Telephones are at every shaft station and hoist room, all connected with the local telephone exchange. In case of power failure, there is an emergency hand-operated pull rope in each shaft. Copies of the Arizona Mine Signal Code are posted at every station and hoist room.

All shaft manways are equipped with suitable ladders; all openings are provided with mesh guards. Steel I-beams are used for roof support at the shaft stations, and the floors are concrete. Main shaft gates are reinforced with rail or I-beams to prevent haulage motors or cars from crashing through into the shaft.

Dust Control

Ventilation

Rock temperatures approaching 100° F. on the lower levels make adequately controlled ventilation necessary for tolerable working conditions. The mine is mechanically ventilated throughout, and fresh air is distributed so that each section of the mine is served by a split of reasonably fresh air.

The main fan, with a capacity of 265,000 cubic feet of air a minute, is on the 1000 level at the bottom of a 13- by 13-foot air shaft. On the discharge side of the fan, the air passes down an inclined raise to the main air shaft. The air shafts are clear of timber or other combustible material for their entire length, permitting free passage of air. The air shaft is cleaned by washing down the accumulated dust at intervals of 2 to 3 months.

Fresh air is taken off on all working levels, and volume is controlled by steel regulator doors that can be set for any desired volume (fig. 4). Auxiliary fans are used to increase the ventilation in portions of the mine offering higher resistance. All raises and development headings are ventilated by 5-horsepower, 7-1/2-horsepower, and 15-horsepower auxiliary blowers with 11-inch or 16-inch pipe or tubing. In raises, the ventilation tubing must extend above the drilling platform.

Wooden and steel ventilation doors are used. "Crashproof" steel doors are installed on all haulage levels. This door was designed following a fatal accident involving a rigid wooden door, is double-hinged, and is smaller than the frame in which it hangs, so that a train can crash through it from either direction. The reverse hinge is secured with stove bolts or by means of a light tack weld. The edges of the door are lined with belting, which minimizes air leaks but permits the door to swing through the frame when crashed. Although trains have accidentally gone through these doors on different occasions, no fatalities or injuries have resulted during the 12 years they have been in use (fig. 5).

Another safety device to avoid crashing doors is a stop, consisting of a lever with a latch and a rope, that holds the door open while the train is

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Figure 4. - Steel regulator door opening from air shaft.

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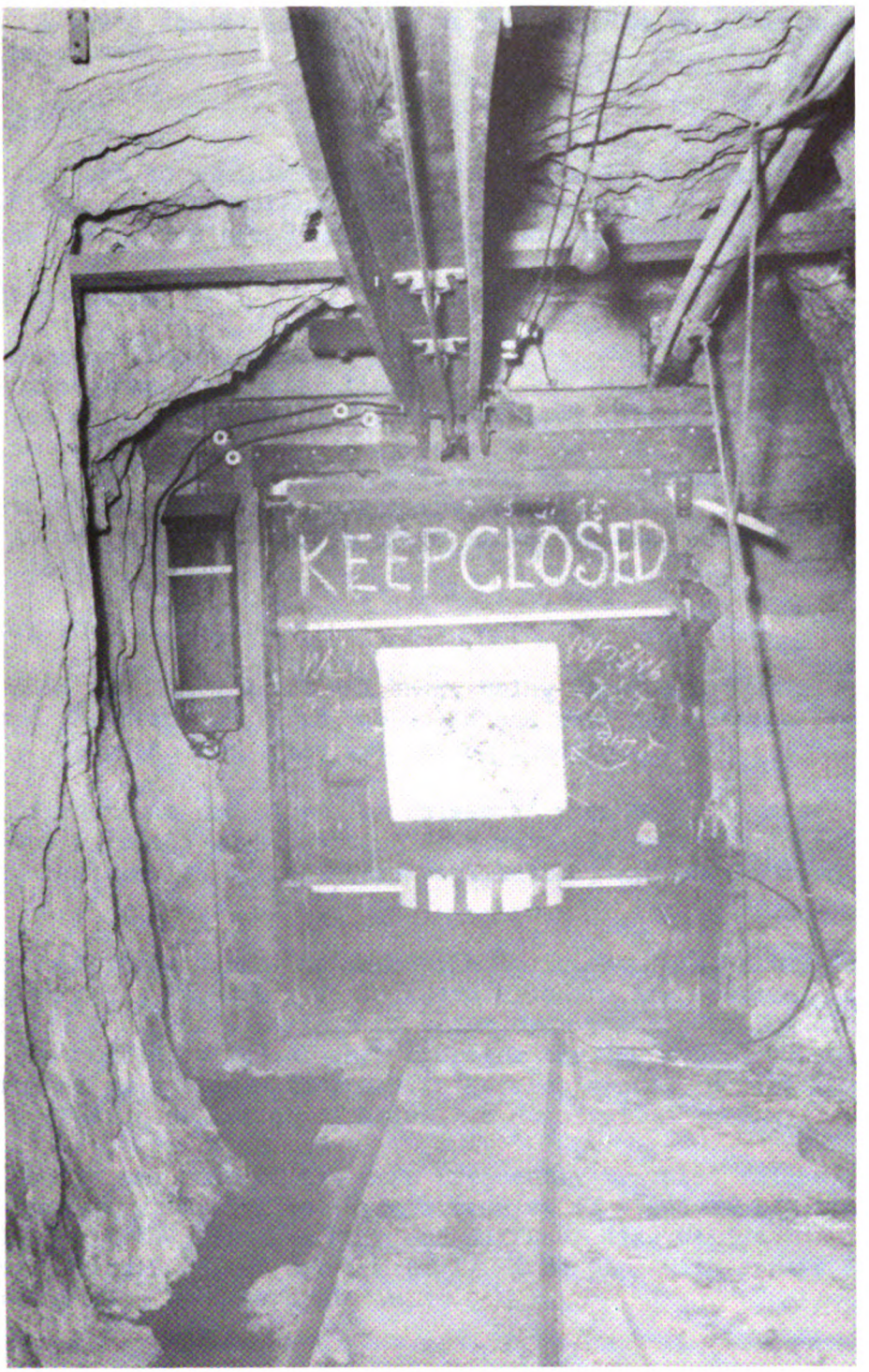

Figure 5. - Steel ventilation door.

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passing through; the door stop can be released by a pull rope after the train has passed. Slow signals, electrically lighted, are installed within 150 feet of either side of the door, and stop lights near the door remind the motorman of the hazard. A white square is painted on each door as an additional warning that the door is closed.

Water in Dust Control

Mine dust is kept to a minimum not only by controlled ventilation but also by the judicious use of water. Printed instructions to be followed at the start of the shift in stopes[8] and drifts[9] are as follows:

Wetting down stope.

1. Turn on flood lights.
2. Connect hose to water line.
3. Wet down muck pile on floor. Wet down back and walls when it is safe to do so.
4. While wetting down, be careful not to go beyond the point to which the stope has been barred down.
5. Avoid spraying water on power lines, cables, slushers, and other equipment.

Preparatory work in drifts.

Wet down the muck, wall, and back, being careful not to advance beyond the point to which the walls and back have been barred down. Keep the muck pile wet during loading.

Similar instructions are given for raises[10] when entering after blasting of the round; but in raise work, wetting down must of necessity follow opening of the manhole, restoration of secondary ventilation, and examination of the face.

Slusher operators wet down the muck pile at intervals to allay dust in the area being worked. At each grizzly where slushers are operated, a cone spray is installed to throw a curtain of water over the top of the chute. This spray is controlled by the slusher operator through a foot valve. Each miner is instructed to wet down thoroughly the area around the drill set-up. All drilling, including collaring of holes, is done wet.

All main drifts and some of the more frequently traveled raises are equipped with spray systems. These sprays consist of standard 1/2-inch pipe couplings drilled with a 3/32-inch hole and diffuser disk welded on by means of a short stem. Each 200-foot section of 1/2-inch pipe with sprays at 10-foot intervals is controlled by a separate valve.

8/ Work cited in footnote 5.
9/ Work cited in footnote 7.
10/ Phelps Dodge Corp., Code of Safe Practice for Raise Mining: Jerome, Ariz., 1941, p. 4.

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Sprays are installed at the shaft pockets to provide a curtain of water over the grizzly while dumping; their use is mandatory. There are two sprays at each skip-loading pocket that are controlled by the skiptender by means of a foot valve. One spray wets the ore that passes into the measuring hopper, whereas the second spray puts a curtain over the top of the hopper to trap any dust that may rise as the hopper is filled.

All underground employees are provided with approved-type respirators, the use of which is required when conditions warrant. The Company supplies replacement filters and handles the upkeep of these respirators.

Check-In-and-Out System

To provide an absolute check on clearing the shift underground, a metal tag is prepared for each man showing his name and number. Each man picks up his tag at the surface time office and hangs it on a special board at a central place on each operating level before proceeding to his working place. The tag is removed by the man when he completes the shift or leaves the level. The shift boss or an assigned man checks the board before leaving the mine to be sure that all men are out of the working places before blasting is done. On reaching the surface, the man returns his tag to the time office. Shift bosses remain at the change house until advised by the time office that all men have been accounted for.

Miscellaneous Safety Items

All sheave blocks used with tugger hoists have a metal guard on the lower end to prevent injury to fingers of operators, when hoisting materials.

Oil houses underground have solid steel doors hung on concrete frames, with a sand floor to absorb drippings. The sand is replaced when saturated. Lighting is by means of electric lights with vaporproof fittings and wiring in conduit. A foam-type fire extinguisher is placed outside each oil house.

Drinking water piped from company-controlled springs in the mountains above the plant serves all levels in the mine. Fresh-water tanks are situated so as to furnish water for each level, to the 3000 level, with a 300-foot head, or 130 pounds per square inch pressure. Many stations have drinking fountains that are tanks with water coils inside. The cooling medium is the expansion of compressed air as it passes through small orifices at the bottom of the tank and rises through the water bath in which the coils are immersed.

Four-foot Calyx holes are used as waste fill raises to stopes and ventilation openings between levels. The drill eliminates many of the hazards of driving a raise, and a smooth bore hole serves as an ideal opening in lowering timber and supplies into a stope.

When development work was started on the lower levels, the No. 8 shaft was protected from possible flooding by the installation of heavy cast-steel water doors set in reinforced-concrete frames a short distance from the shaft. To insure their readiness in case of emergency, these doors are actually closed during the general safety inspections.

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Pilot holes are drilled ahead of development faces in exploratory drifts. Although flooding has never taken place in the mine, water at 110° F. and approximately 1,000 pounds per square inch pressure was cut by a pilot hole in a 4500-level drift. The water pressure has since been relieved.

Three pump stations have adequate capacity to handle the drainage water from the mine. Stand-by equipment is installed for use in case of break-downs.

FIRE PROTECTION

On the surface, a fire crew, with the surface boss acting as fire chief, holds regular monthly drills. The surface fire crew is composed of one man from each shop. The municipal fire department at Jerome, 1 mile from the 500-level yard, is available for emergencies on surface.

In the 500-level yard are eight hydrants, nine monitors, and five risers, with additional risers inside buildings and a manually operated sprinkler system in the change-room attic. Water is stored in seven tanks having a storage capacity of 859,000 gallons under a 290-foot head to the 500 level. Surface water mains are 6 and 8 inches in diameter. All outside water outlets are 2-1/2 inches and inside outlets are 1-1/2 inches in diameter. Hose is stored in nearby hose boxes with a 3/4-inch nozzle and wrenches. These are inspected monthly and tested under pressure occasionally. About 115 carbon tetrachloride and foam-type extinguishers, inspected semiannually, are distributed to surface buildings and underground stations, including all electrical installations.

Alarms on fires discovered underground are sent to the hoist engineer by sending a nine-bell signal on the cage call system. The hoist engineer sends the alarm throughout the mine by flashing the lights nine times on the main mine switch. The signal is repeated three times. Alarm can also be given by use of a stench in the compressed-air lines. Underground firefighting equipment is in two locked boxes mounted on mine trucks and containing all the necessary tools. The key for each box is hung inside a glass window on the side of the box. A portable mine telephone with a 1000-foot reel, an electric fan, and a compressed-air blower are mounted on trucks for emergency use. Compressed-air lines can be converted to water lines for fire fighting. The valves at each station are numbered, with instructions posted as how to set each valve for turning water into the air lines. Frequent outlet connections are provided in underground water lines, and 1-1/2-inch fire hose with permanent nozzles are located where needed.

Most of the welding is done in a fire-resistant shop. When welding at other places, a fire extinguisher is kept at hand; inspection is made before and after the work is done. Before and after welding or burning is done underground, the place is thoroughly wet down.

Other fire-prevention rules prohibit smoking at the No. 8 shaft stations, on the cages, at battery charging stations, around magazines and similar locations, or when carrying or loading explosives.

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MINE RESCUE

The mine rescue crew, which also serves as the underground fire department, comprises 24 men normally. Owing to labor turnover, this number fluctuates from a minimum of 20 to a maximum of 28. The safety engineer and a repairmen are responsible for the upkeep of equipment, which is inspected monthly. Eight men are trained one day each month, so that each crew member receives 8 hours training once every 3 months. The men make a complete check of the apparatus and wear the machines inside the mine for a 2-hour period, during which they set timbers, build brattices, hold fire drills, or combat imaginary fires. The apparatus is cleaned, recharged, and tested after wearing, and its condition is recorded on a blackboard in the apparatus room. After recharging with Cardoxide, the apparatus number, date, and name of the team member who serviced the apparatus are recorded on the label of the empty container, which is kept as a record of the freshness of the Cardoxide until the apparatus is used again. The rest of the shift is devoted to discussion of mine rescue and fire fighting.

The mine rescue crew is trained according to Bureau of Mines standards and is examined periodically by a Bureau of Mines representative. Some replacements of team members are due to promotions; many of the shift bosses were formerly on teams.

The mine rescue equipment consists of 5 sets of McCaa and 10 sets of Gibbs 2-hour apparatus. Additional equipment of the well-equipped mine rescue station includes 12 All-Service gas masks, oxygen inhalators, oxygen pumps, carbon monoxide detectors, flame safety lamps, life line, flashlights, mine rescue telephone, and necessary repair parts. A minimum supply of 1,400 pounds of Cardoxide is stocked at the mine. Equipment is stored, ready for use, in humidor cabinets in a large, well-lighted apparatus room. Hot and cold running water are available, and the room is heated during cold weather.

In the past few years oxygen breathing apparatus was required on three different occasions for minor underground fires. Apparatus was necessary for fire fighting and reconnaissance. The team has also been called upon to assist in mine rescue work at nearby properties.

FIRST-AID EQUIPMENT

Every workman carries a safety kit containing the following articles:

4 adhesive compresses
1 small 2" x 48" bandage compress
1 3" x 3" bandage compress
2 yards 3" gauze bandage
1 small roll 1/2" adhesive tape
1 ammonia ampoule

First-aid boxes and stretchers are on hand at all the active shaft stations and other strategic locations to supplement the small safety kits in handling more severe injuries (fig. 6). The boxes contain:

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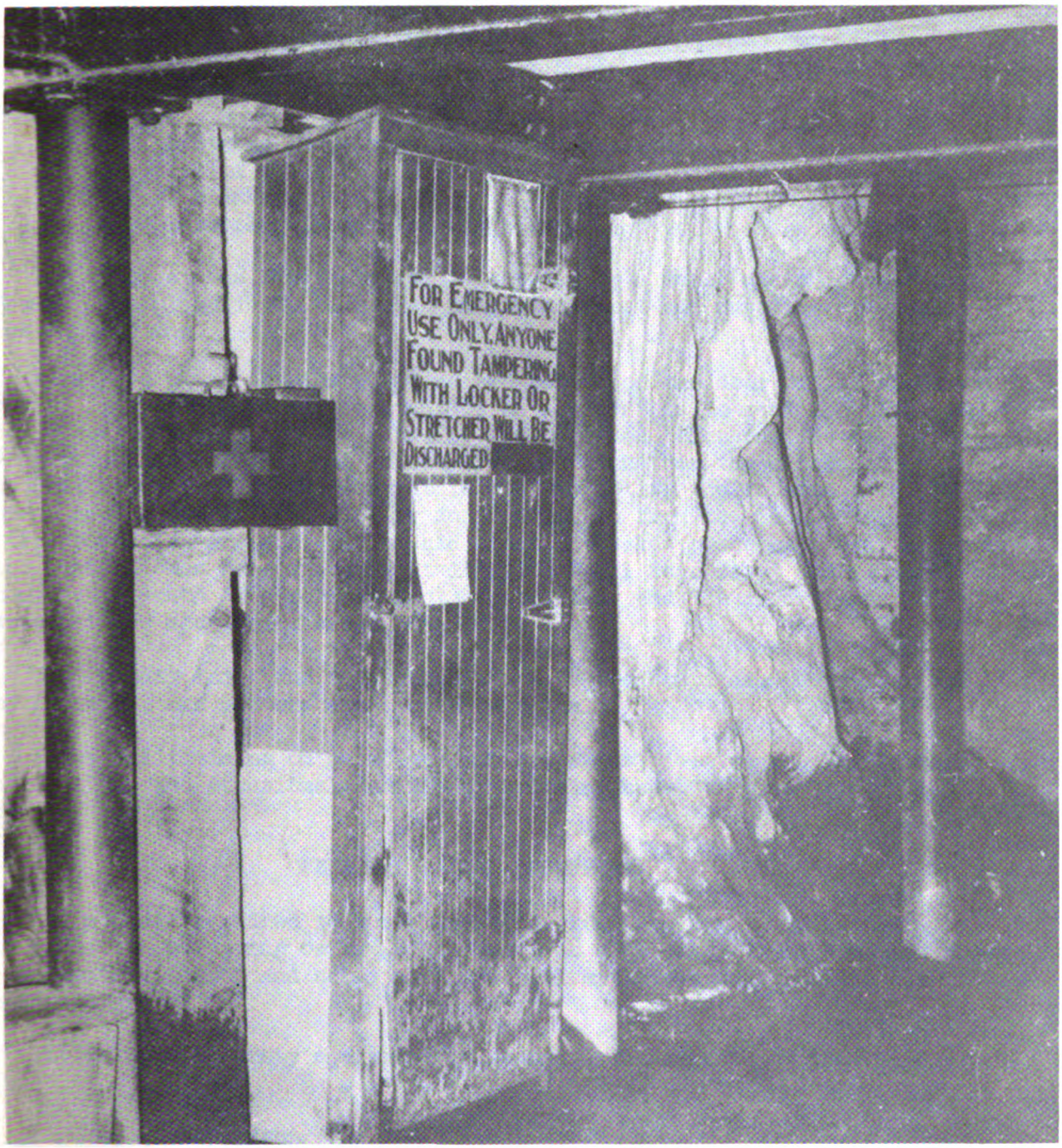

Figure 6. - First-aid supplies and stretcher cabinet at shaft station.

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4 to 6 small splints for the arms
Supply of waste for splint padding
12 to 15 three-inch compress bandages
10 to 12 two-inch compress bandages
12 to 15 one-inch compress bandages
8 triangular bandages
12 to 15 ammonia inhalants

Stretcher cabinets contain:

1 Stokes Navy-type wire basket stretcher
Set of splints
2 blankets
1 bottle vinegar for lamp burns

The latch on the first-aid box is covered by a small glass mounted in a frame. The glass is to be broken only when first-aid supplies are needed to treat injured men.

First-aid emergency instructions are posted on the door of the stretcher cabinet. The procedure in the event of an accident is to send the first man encountered to the station to ring for the cage and telephone the time office giving nature of accident and information as to whether the ambulance or doctor is needed. The next man met is sent to notify the foreman or boss. Someone must accompany the sick or injured person from the mine until relieved or transportation arrives. First-aid treatment takes precedence over all other rules listed. Men receiving slight injuries shall have first aid rendered by a competent person, the foreman must be notified, and the injury must be treated at the hospital the same day.

The company maintains a dispensary and 54-bed hospital. Nurses are on duty 24 hours, and doctors are available on call.

First-aid training on a 100-percent basis was given at the United Verde mine in 1936, and occasional additional training has been given since that time.

PERSONAL SAFETY EQUIPMENT

All men are required to wear hard-toed shoes and hard hats in the mine. Wearing of loose-fitting or ragged clothing is discouraged. Each man is urged to use leather gloves and carry a watch. All employees use electric cap lamps underground.

The following safety equipment is issued under deposit by the Company:

Goggles
Respirator
First-aid kit completely filled
Match box
Safety codes

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The respirator is used on such jobs as chute pulling or skip loading where dust concentrations may be high momentarily. Safety belts and chains are provided where needed.

All miners are equipped with folding eyeshields attached to the under side of the brim of the hat. In addition, timbermen and trackmen have spectacle-type goggles. For breaking boulders and blowing out drill holes with a blowpipe, the use of full-coverage goggles is required. In the outside shops, spectacles must be worn during the entire working period.

ACCIDENT DATA

Table 1 gives the accident-frequency rates for the United Verde mine for the years 1935-1947. These data indicate the results obtained by the safety program, which has kept the frequency rate consistently below the average for similar underground metal mines.

When the Phelps Dodge Corp. took over the property in February 1935, the United Verde Copper Co. had already embarked upon a comprehensive safety program, which had brought the accident-frequency rate per million man-hours exposure down to 18.59 for the last 4 years of operation, as compared with a frequency rate of 81.76 for the preceding 5 years. When it is considered that during 1926 and 1927 the frequency rate was 136.73, whereas during 1946 and 1947 a frequency rate of 14.28 was achieved, the improvement is even more apparent.

TABLE 1. - Accident frequency, United Verde mine, 1935-1947

Year	Lost-time accidents	Man-hours worked	Frequency rate 1/
1947----------	16	1,193,240	13.41
1946----------	16	1,048,080	15.27
1945----------	19	1,088,680	17.45
1944----------	26	1,669,768	15.57
1943----------	52	2,544,568	20.44
1942----------	38	2,856,592	13.30
1941----------	34	2,402,352	14.15
1940----------	26	1,831,224	14.20
1939----------	18	1,422,282	12.66
1938----------	13	1,280,936	10.15
1937----------	19	1,580,936	12.02
1936----------	13	1,358,088	9.57
1935----------	20	1,052,840	18.99
Total---------	310	21,329,586	14.49

1/ The accident-frequency rate is defined as the total number of lost-time accidents, fatal and nonfatal, per million man-hours of exposure.

CONCLUSIONS

The United Verde mine has developed an accident-prevention program that sustains the interest of all employees through their active participation. The

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main features of the program are the codes of safe practice, safety meetings, systematic safety inspections, accident investigations, dust control, first-aid and mine rescue training, and physical examinations before employment. Close supervision and constant instructions by the bosses is the keystone of a successful safety program.

The codes of safe practice provide a standard for safe working methods, and their value is increased by the education of employees in their use and application. Accident investigations develop methods for prevention of similar occurrences and forcibly instill safety-consciousness in the individual directly involved. The judicious publicity of the investigations and discussions of accidents promotes safety-consciousness to some degree in the entire personnel. Submitting safety suggestions is encouraged, and all such suggestions are given prompt consideration and attention.

The program should be regarded as a product of evolution, with the attainment of no accidents as the ultimate goal. It serves as a means of recognition of and protection against new hazards and mitigation, if not elimination, of those risks that continue to cause injuries to workmen in underground mines.

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